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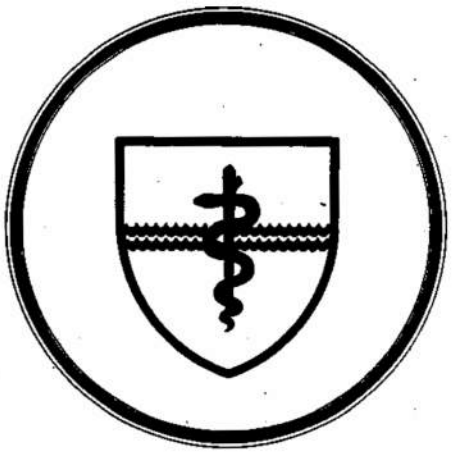

REPORT NUMBER 946

WORK AND REST ON NUCLEAR SUBMARINES

by

Arthur N. BEARE, Robert J. BIERSNER, Kenneth R. BONDI, and Paul NAITOH

Naval Medical Research and Development Command
Research Work Unit ZF58.524.004-9023

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January 1981

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SUMMARY PAGE

THE PROBLEM

To determine the workload and adequacy of sleep of personnel serving on Fleet Ballistic Missile submarines.

FINDINGS

Workload (watch standing, off watch work, and study) averages about 12 hours a day, with considerable individual variation. The smallest 30-day average recorded was 7.4 hours; the largest was 15.6 hours. For all ranks, study constituted a significant proportion of recorded work. Sleeping habits were affected by the 18-hour activity cycle created by the 6-hours-on, 12-hours-off watch schedule. Sleep may be considered mildly fragmented in that men averaged 1.3 sleep episodes of somewhat less than 6 hours duration in 24 hours, but the total daily quantity of sleep was judged adequate. Subjective sleep quality was slightly lower on patrol than in a post-patrol period.

APPLICATION

This report gives the most detailed description of the submarine work day available and may be of use in manpower management.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Naval Medical Research and Development Command Research Work Unit ZF58.524.004-9023, "The Physiological, Biochemical, and Psychological Effects of 18-Hour Work-Rest Cycles During a 2-Month Submarine Patrol." The present report was submitted for review on 18 November 1980, approved for publication on 29 December 1980. It has been designated as NavSubMedRschLab Report No. 946.

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ABSTRACT

Hours of work and sleep were recorded in daily activity logs by 46 enlisted men on two Fleet Ballistic Missile submarines during routine patrols. Total working time (watch standing, non-watch work, and study) averaged 12 hours a day. Daily sleep time averaged 8 hours a day on one ship and 7.5 on the other. Sleep was mildly fragmented in that the men averaged 1.3 sleep episodes, of somewhat less than 6 hours duration, in 24 hours. Thirty of the men were standing watch on a 6-hours-on-12-hours-off rotation which effectively imposed an 18-hour cycle on their activities. Questions in the logs were used to assess subjective sleep quality and sleepiness. Sleep quality on patrol was not as good as in a post-patrol period, but the difference between on- and off-patrol sleep quality was small. The 6-on-12-off watch schedule appeared to result in less sleep fragmentation than the traditional 4-on-8-off schedule employed on other Naval ships.

WORK AND REST ON NUCLEAR SUBMARINES

1. INTRODUCTION

At any given moment, approximately 3500 crewmen on U.S. Navy nuclear submarines are living on an activity cycle that is dramatically different from the 24-hour day. This study is an investigation of the adequacy of sleep obtained by men following an 18-hour cycle of work and rest in an isolated community.

Aboard naval vessels the pattern of activity, including sleep, is dominated by the watch schedule. In the early days of the nuclear submarine force, the watch schedule was a variant of the traditional 4-hours-on, 8-hours-off routine employed by the rest of the Navy. The traditional watch schedule was not well suited to some of the lengthier drills and maintenance procedures required by the submarine's sophisticated machinery. In addition, the 8-hour interval between watches made it difficult to perform the numerous off-watch duties and still obtain an uninterrupted sleep of reasonable length (Stolgitis, 1969). Informal experiments with various watch schedules gradually led to the adoption of a 6-hour watch period for submarines. For a standard three-section (shift) watch, this gives 6 hours on watch and 12 hours off. Crewmen prefer this schedule to the traditional one. Approximately 75% of enlisted men serving aboard U.S. Navy submarines stand watch on this schedule, hereafter referred to as a 6:12 rotation. Most officers and some senior enlisted men stand watch on a four-section rotation, i.e., 6 hours on and 18 off.

The 6:12 rotation is of particular interest because the activity cycle it creates is an 18 hour "day" instead of the 24 hour circadian cycle of sleep and wakefulness to which men are conventionally adapted. Schaefer, Kerr, Buss, and Haus (1979) reported that the 6:12 watch schedule disrupted the 24-hour cycles associated with oral temperature, pulse and respiration rates, and systolic and diastolic blood pressure. The 18-hour activity cycle, however, did not entrain a simple 18-hour cycle. A complex rhythm developed for all measures on all subjects, in which both 24- and 18-hour components were detectable. Additional components, some of them harmonically related to the 18- or 24-hour cycles, were also detected in some of the measures. It should be noted that traditional watch schedules also disrupt circadian rhythms. Studies by Colquhoun, Paine, and Fort (1975, 1978) of British submariners standing watch on a variant of the 4:8 schedule found that the variation of the oral temperature was reduced and the usual circadian periodicity disappeared.

It can be speculated that the alteration of the rhythm of various physiological processes may affect emotional state or work efficiency, but such effects have yet to be demonstrated. The importance of adequate sleep, however, has been well documented (see Johnson and Naitoh, 1974), and the 6:12 watch schedule does demand a significant rearrangement of sleep habits.

The present report is a description of patterns of work and sleep among men serving on fleet ballistic missile (FBM)

submarines. These activity data contribute to our knowledge of shipboard living conditions by showing in detail how time, other than sleep, is spent. Kleitman's 1949 report on life aboard a diesel submarine and a few studies conducted at the Naval Health Research Center (Naitoh and others, 1971, 1973, 1976; Johnson, 1977) described shipboard sleep patterns, but did not document waking activities. Williams, Malone, and Bokesch (1975) obtained estimates of the various components of workload on surface ships, but did not treat sleep in detail. The only study reporting both work and sleep patterns is a recent examination of the workload and performance of Navy pilots and Landing Safety Officers by Brictson and Young (1980).

In the present study, two specific questions were asked. First, what is the workload aboard operational submarines? Secondly, is the total sleep time long enough to prevent chronic partial sleep deprivation?

2. METHOD

The data presented in this report were obtained from activity logs issued to submarine crewmen in conjunction with separate studies of physical activity and cyclic variations in oral temperature and mood (Naitoh, Beare, Biersner, & Englund, in preparation). In the interval between these two projects, the format of the logs was changed to include scales for assessing sleep quality and mood. Thus, in this report, the analysis of workload and sleep times is based on a larger sample than the analysis of sleep quality and mood.

2.1 Subjects

The subjects were 46 enlisted[1] men from the crews of two U.S. Navy FBM submarines which will be identified as Ship A and Ship B. Ship A was on a 40-day deployment and Ship B was on a routine 70-day strategic deterrent patrol. All subjects were volunteers. About one-third of the men originally issued logs failed to return them or did not complete them properly. Forty-six men returned usable logs. The 23 men from Ship A were relatively senior in rank and only seven were standing watch on the 6:12 schedule. The Ship B sample included a wider distribution of age and rank, and all but four men stood 6:12 watches throughout the patrol. Average rank, age, and years of submarine service are presented in Table 1. In addition, 11 men from the Ship B sample returned supplemental logs covering a 10-day post-patrol period.

Table 1
Sample Demographics

Ship	n	Rank[1]	Age	Years[2]
A	23	PO-1*	28.7/5.9**	7.1/5.7
B	23	PO-2	25.4/5.2	3.9/4.4

1 Average Rank
2 Years assigned to submarines
*Petty Officer First Class
**Mean/Standard Deviation

2.2 Materials

Each subject recorded his daily activities in an activity log consisting of a graphic activity

1 Footnotes are at the end of the paper.

record and (for the Ship B sample) supplemental scales for assessing sleep quality and mood. The log depicted in Figure 1 (overleaf) is that issued to Ship B. The Ship A logs had identical activity records but did not have the supplemental scales. To record his activities, the subject was instructed to select the proper row of the activity record and simply draw a line from the time he began a particular activity until the time he completed it. In the center of the log sheet is a brief mood scale composed of 15 adjectives. To the left of the mood scale is a set of four questions for assessing subjective sleep quality taken from the Sleep Survey used by Hartman and Cantrell (1967). The Stanford Sleepiness Scale (SSS) of Hoddes, Zarcone, Smythe, Phillips and Dement (1973) appears to the right of the mood scale. The log is an elaboration upon the graphic sleep log developed by Naitoh, Townsend, and Greenwood (1969) at the Naval Health Research Center.

Subjects were instructed to complete the activity record and the sleepiness and mood scales before retiring for a sleep period. Upon awakening, they completed the sleep quality questions and mood scale. Two additional SSS, two sets of sleep quality questions, and four additional sets of the adjective checklist were printed on the back of each log page for use in the event more than one sleep period was taken in the 24-hour period.

2.3 Analysis

Analysis of the activity records consisted of tabulating the hours logged for various activities. The time devoted to each activity is summarized as a daily average, i.e., the number of hours out of 24. For Ship A, 31 days (1 month) were analyzed as a single block. For Ship B, where the record was much longer, three 10-day sub-samples were taken, one early, one in the middle of, and one late in the patrol. These were combined and are reported as a single 30-day average.

2.3.1 Work and Sleep. The graphic activity logs were read to the nearest quarter-hour and daily averages calculated for each activity by dividing the total time logged by the length of the sampling period in days.

Any logged sleep time over one-half hour was treated as a sleep episode. Episodes separated by one-half hour or more were considered separate episodes. Sleep periods interrupted by waking intervals shorter than one-half hour were recorded as a single episode of a length equal to the total sleep time excluding the waking interval. From the tabulation of sleep episodes, three statistics were calculated: (1) the average quantity of sleep given by the mean daily sleep time (Hr/24); (2) the mean number of sleep episodes per 24-hour period (#EP/24); and (3) the regularity of sleep, as expressed by the coefficient of variation, $\sigma/\bar{x}$, between the standard deviation and the mean of sleep episode duration. (Baekeland and Hartmann, 1971). The magnitude of this index increases as

PART I: Activity Record

Date/Time when filled out: _____/_____

ACTIVITY LOG

	0000		0300		0600		0900		1200		1500		1800		2100		2400
Watch																	
Add. Duty																	
Study																	
Recreation																	
Sleep																	
Meals																	
Headaches																	
Medication																	

PART II: Upon arising

How much trouble did you have going to sleep last night?

___ none
___ slight
___ moderate
___ considerable

How rested do you feel?

___ well
___ moderately
___ slightly
___ not at all

Do you feel that you could have used more sleep?

___ Yes ___ No

Number of times that you woke up during the night. ___

Date/Time_____/_____

Upon arising					Before retiring				
contented	vv	v	?	no		vv	v	?	no
energetic	vv	v	?	no		vv	v	?	no
steady	vv	v	?	no		vv	v	?	no
happy	vv	v	?	no		vv	v	?	no
calm	vv	v	?	no		vv	v	?	no
vigorous	vv	v	?	no		vv	v	?	no
lively	vv	v	?	no		vv	v	?	no
peppy	vv	v	?	no		vv	v	?	no
pleased	vv	v	?	no		vv	v	?	no
activated	vv	v	?	no		vv	v	?	no
satisfied	vv	v	?	no		vv	v	?	no
good	vv	v	?	no		vv	v	?	no
active	vv	v	?	no		vv	v	?	no
cheerful	vv	v	?	no		vv	v	?	no
alert	vv	v	?	no		vv	v	?	no

NOTES: _____

_____

PART III: Before retiring

What best describes your present feelings?

___ Feeling active and vital; alert; wide awake.

___ Functioning at a high level; not at peak, but able to concentrate.

___ Relaxed, awake, responsive, but not at full alertness.

___ A little foggy; let down; not at peak.

___ Foggy; slowed down; beginning to lose interest in remaining awake.

___ Sleepy; woozy; prefer to be lying down; fighting sleep.

___ Almost in reverie: sleep onset soon; losing struggle to remain awake.

Date/Time: _____/_____

(Extra Parts II and III on the opposite page for those who slept more than once during this 24-hour period)

FIGURE 1. Page of the "Personal Activity Log" issued on Ship B. The logs issued on Ship A did not have the sleep quality, sleepiness, and mood scales (parts II and III), but the graphic activity record was the same.

the variability of sleep episode durations increases.

2.3.2 Sleep Quality and Mood. The supplemental scales of the Ship B logs were scored as follows. The question: "How much trouble did you have going to sleep last night?" (SQ-1) was scored on a 4-point scale with "none" scored as 1 and "considerable" as 4. "How rested do you feel?" (SQ-2) was scored on a 4-point scale with "well" scored as 1 and "not at all" scored as 4. "Do you feel you could have used more sleep?" (SQ-3) was scored 1 for "yes" and 0 for "no." Reported averages are thus the proportion of times this question was answered in the affirmative. "How many times did you wake up last night?" was answered "zero" the vast majority of the time, so this item was not tabulated.

The SSS was scored on a 7-point scale, with "feeling active and vital; alert; wide awake" scored as 1 and "almost in reverie; sleep onset soon; losing struggle to remain awake" scored as 7.

The adjectives comprising the mood scales are from the "Pleasantness" scale of the Mood Questionnaire developed by Ryman, Biersner, and LaRocco (1974). This has two sub-scales. The adjectives *contented, steady, happy, calm, pleased, satisfied,* and *good* make up the "Happiness" (MH) scale. The "Activity" (MA) scale is made up of *energetic, vigorous, lively, active, cheerful,* and *alert*. The first four of the six items comprising the activity scale are taken from the Thayer (1967) "activation" scale. Two additional items from that scale, *peppy* and *activated,* are included, yielding a shortened (the item *full of pep* was omitted) Thayer (TA) scale as well. The format and scoring was the same as that of the Thayer scales. The respondent indicated the degree to which the adjective applied at the time the scale was filled out by circling one of the symbols next to the word. A "VV" was circled if the adjective definitely applied; a "V" if it applied somewhat or slightly; a "?" if he was uncertain; and "no" if the adjective definitely did not apply. These responses were scored from 1 ("no") to 4 ("VV"). The scale value is the mean of the scores for the items comprising the scale. High values thus indicate greater "happiness", "activity", or "activation."

2.3.3 Health. The number of visits to the ship's dispensary was recorded to obtain an objective (if crude) indication of the physical well-being of the men participating in the study on Ship B.

2.3.4 Correlations Among Measures. Correlations among the statistics describing work, sleep, and subject characteristics (age, rank, years of submarine service, and number of patrols completed) were computed for the men of both samples. The correlation among these variables and number of dispensary visits, sleep quality, and mood measures were computed for the men from Ship B. All correlations reported are statistically significant at the $p < .05$ level or higher.

3. RESULTS

3.1 Work

The number of hours logged for watch, additional duty (ADDU), and

Table 2

Daily Average of Recorded Work

Ship A						Ship B					
Subject	Rate	Watch	ADDU	Study	Rotation	Subject	Rate	Watch	ADDU	Study	Rotation
A-1	MMC	7.87	1.77	2.01	6:12	B-1	ETC	8.50	3.55	0.00	6:12
A-2	MM1	7.70	2.10	0.00	6:12	B-2	MM1	7.86	5.14	0.08	6:12
A-3	MM1	7.74	1.62	1.40	6:12	B-3	MM1	7.18	2.75	2.90	Mixed
A-4	EM1	8.13	5.16	0.53	6:12	B-4	ET1	8.10	2.14	3.41	6:12
A-5	MM2	7.40	2.74	2.98	6:12	B-5	MM2	7.86	6.58	0.93	6:12
A-6	FTG2	8.13	1.37	1.51	6:12	B-6	EM2	5.97	4.08	5.58	Mixed
A-7	ETN2	8.19	7.46	0.00	6:12	B-7	IC2	9.33	2.85	3.01	6:12
A-8	QMCS	6.02	3.84	1.94	6:18	B-8	ET2	5.97	4.08	5.58	6:12
A-9	MMC	5.89	6.38	0.00	6:18	B-9	EMC	8.18	1.22	0.48	6:12
A-10	ETC	5.75	3.00	1.83	6:18	B-10	MTC	7.02	3.23	2.74	Mixed
A-11	ETC	6.27	8.64	0.60	6:18	B-11	MM1	7.23	2.92	0.00	6:12
A-12	ET1	6.18	1.60	2.63	6:18	B-12	MT1	8.38	2.21	4.43	6:12
A-13	FTB1	6.39	0.68	1.85	6:18	B-13	STS1	8.20	2.04	0.00	6:12
A-14	QM2	6.48	1.75	0.00	6:18	B-14	MM1	7.23	2.10	0.00	6:12
A-15	QM2	6.66	3.95	0.51	6:18	B-15	RM2	8.30	2.43	1.15	6:12
A-16	ETN2	5.94	1.98	1.77	6:18	B-16	FTG2	7.81	3.34	0.15	6:12
A-17	ETN2	6.20	2.35	1.27	6:18	B-17	TM2	7.20	0.23	0.00	6:12
A-18	ETN2	6.23	6.80	0.16	6:18	B-18	ET3	8.40	1.15	6.00	6:12
A-19	SKC	1.02	10.02	0.00	NONE	B-19	ET3	8.42	2.31	1.04	6:12
A-20	RMC	6.74	1.08	0.00	Mixed	B-20	SN	8.22	1.91	4.20	6:12
A-21	YN1	0.00	9.31	1.16	NONE	B-21	SN	9.36	0.89	3.46	6:12
A-22	RM1	7.29	1.80	2.85	Mixed	B-22	SKSN	8.10	0.13	5.04	6:12
A-23	RM1	6.63	3.82	1.85	Mixed	B-23*	SN	2.80	7.04	2.12	Mixed
Mean	(6:12)	7.88	3.33	1.17	n=7	Mean	(6:12)	8.15	2.40	1.96	n=19
SD	(6:12)	.29	2.29	1.00		SD	(6:12)	.58	1.55	2.07	
Mean	(6:18)	6.18	3.72	1.14	n=11	Mean	(all*)	7.96	2.53	2.20	n=22*
SD	(6:18)	.27	2.53	.92		SD	(all*)	.76	1.49	2.03	

Mixed watches mean that the subjects stood both 6:12 and 6:18 watches, depending on the sample periods. Subjects A-19 and A-21 appeared to keep regular office hours. *Subject B-23 was not included in the watch average.

study for each subject are given as daily averages in Table 2.

3.1.1 Watch. Watch is the largest single component of the workload, accounting for between 57% and 67% of the total working time. Watch standing required an average of 8.08 hours a day on the 6:12 rotation and 6.18 hours on the 6:18.

3.1.2 Non-Watch Work. Subjects A-19 and A-21 were not included in the computation of non-watch work because they appeared to keep regular office hours in lieu of standing watch, nor was subject B-23, whose primary duty, cooking, was also logged as ADDU. Differences in the number of hours logged as non-watch work were striking, ranging from a daily average of 8 minutes (subject B-22) to over 8 hours (A-11). Men working on the "easier" 6:18 watch schedule tended to put in more hours of additional duty (3.7 ± 2.5) than men on the 6:12 watch (2.6 ± 1.8), but the variation within these groups was so large that the difference was not statistically significant. In contrast to the hours spent standing watch, the amount of time recorded as additional duty by a given individual varied a great deal from one ten-day subsample to the next in the logs from Ship B. The difference between the largest and the smallest 10-day totals logged by an individual averaged 1.6 hours, which is large in comparison with the 30-day average of 2.5 hours.

3.1.3 Study. Study time was included in the compilation of workload because a significant amount of study is required of men in most technical ratings, and success in competitive examinations is required for promotion. The average logged study time was 1.68 hours a day. The amount of study recorded on Ship B (2.20 hours) was significantly greater than on Ship A (1.17 hours): $t(44) = 2.17$, $p = .035$.[2] There was a small negative correlation (-.37) between logged study time and rank.

3.1.4 Total Workload. Watch, additional duty, and study were summed to provide an estimate of total workload. There was a small negative correlation (-.25) between rank and total workload. The average daily workload was 11.3 hours for Ship A and 12.7 hours for Ship B. The difference, which is not statistically significant, is due to the greater proportion of men standing 6:12 watches in the Ship B sample. For both ships combined, the average workload was about 12 hours out of every 24, or 84 hours a week.

3.2 Sleep

Sleep quantity and sleep quality statistics for the men of both ships are presented in Table 3 (overleaf). Sleep quantity statistics for 11 men of Ship B who returned post-patrol activity logs are given in Table 4.

3.2.1 Quantity of Sleep. The total amount of sleep obtained daily averaged 8.39 ± 1.4 hours for Ship A and 7.55 ± 1.26 hours for Ship B ($t(44) = 2.12$, $p = .040$). The average duration of each sleep episode was also longer on Ship A (6.52 ± 1.58 vs 5.70 ± .84: $t(44) = 2.20$, $p = .033$). The men on Ship B averaged about 50 minutes less sleep

Table 3

Quantity, Frequency, and Regularity of Sleep

Ship A					Ship B							
Subj.	HR/24	$\sigma/\bar{x}$	#EP/24	Rotation	Subj.	HR/24	$\sigma/\bar{x}$	#EP/24	SQ-2	SQ-3	SSS	Rotation
A-1	8.02	.38	1.58	6:12	B-1	8.00	.44	1.50	----	----	----	6:12
A-2	9.92	.42	1.53	6:12	B-2	6.36	.41	1.43	2.62	.90	3.28	6:12
A-3	9.42	.36	1.45	6:12	B-3	8.50	.32	1.20	1.89	.16	3.64	Mixed
A-4	6.15	.37	1.50	6:12	B-4	7.30	.38	1.37	1.52	.26	4.51	6:12
A-5	7.60	.44	1.45	6:12	B-5	4.75	.24	1.27	2.15	.62	3.38	6:12
A-6	9.29	.37	1.32	6:12	B-6	6.49	.34	1.13	2.58	.64	4.99	Mixed
A-7	7.01	.36	1.32	6:12	B-7	6.88	.36	1.47	2.14	.65	3.92	6:12
A-8	7.68	.35	1.32	6:18	B-8	7.18	.11	1.30	1.90	.00	3.40	6:12
A-9	8.36	.30	1.10	6:18	B-9	9.10	.44	1.77	2.25	.63	2.64	6:12
A-10	7.75	.34	1.16	6:18	B-10	8.05	.26	1.17	1.36	.27	3.59	Mixed
A-11	6.89	.45	1.54	6:18	B-11	7.96	.51	1.73	2.03	.45	4.72	6:12
A-12	7.44	.35	1.15	6:18	B-12	7.03	.37	1.30	2.74	.23	4.68	6:12
A-13	9.65	.41	1.52	6:18	B-13	8.64	.43	1.67	1.84	.30	3.44	6:12
A-14	9.08	.29	1.10	6:18	B-14	9.61	.52	1.57	1.72	.26	1.47	6:12
A-15	8.37	.32	1.06	6:18	B-15	7.75	.37	1.37	1.68	.88	3.99	6:12
A-16	8.13	.55	1.35	6:18	B-16	8.55	.32	1.37	2.71	.74	2.76	6:12
A-17	5.23	.65	1.42	6:18	B-17	9.73	.42	1.35	2.42	.80	4.29	6:12
A-18	8.20	.30	1.06	6:18	B-18	6.14	.50	1.15	2.24	.77	4.49	6:12
A-19	8.71	.44	1.39	None	B-19	8.19	.43	1.40	2.13	.47	3.26	6:12
A-20	11.80	.29	1.23	Mixed	B-20	5.20	.39	1.00	1.84	.20	2.59	6:12
A-21	9.85	.28	1.00	None	B-21	7.65	.43	1.27	1.99	.37	4.65	6:12
A-22	8.37	.48	1.39	Mixed	B-22	7.92	.31	1.20	2.04	.47	4.28	6:12
A-23	8.81	.37	1.13	Mixed	B-23	6.79	.16	1.10	2.62	.97	3.39	Mixed
Mean(6:12)	8.20	.39	1.45	n=7	Mean(6:12)	7.58	.39	1.39	2.11	.50	3.71	n=19
SD (6:12)	1.39	.09	.10		SD (6:12)	1.34	.10	.19	.35	.26	.87	
Mean(6:18)	8.10	.39	1.24	n=13*	Mean(all)	7.55	.36	1.35	2.11	.50	3.74	n=23
SD (6:18)	1.20	.09	.18		SD (all)	1.26	.10	.20	.39	.27	.84	

HR/24 = mean total sleep duration in hours per 24-hour day. #EP/24 = mean number of sleep episodes per 24-hour day. $\sigma/\bar{x}$ = sleep regularity index. SQ-2 = sleep quality measure #2. SQ-3 = sleep quality measure #3. SSS = Stanford Sleepiness Scale. Mixed = worked under both 6:12 and 6:18 schedules, depending on the patrol period.

*The men on Ship A keeping "office hours" are included in the 6:18 totals.

Table 4

Comparison of Sleep On and Off Patrol

	On Patrol			At Home			Week Nights Only	
Subject	HR/24	$\sigma/\bar{x}$	EP/24	HR/24	$\sigma/\bar{x}$	EP/24	HR/24	$\sigma/\bar{x}$
B-3	8.50	.32	1.20	8.22	.16	1.00	7.58	.09
B-5	4.75	.24	1.27	7.05	.18	1.00	----	---
B-6	6.49	.34	1.13	7.06	.23	1.00	6.83	.27
B-9	9.10	.44	1.77	7.80	.24	1.00	7.17	.16
B-10	8.05	.26	1.17	7.55	.06	1.00	7.36	.03
B-12	7.03	.37	1.30	8.18	.09	1.00	7.79	.05
B-13	8.64	.43	1.67	8.45	.17	1.00	8.36	.17
B-16	8.55	.32	1.37	8.83	.11	1.00	9.08	.12
B-17	9.73	.42	1.35	7.92	.09	1.00	7.82	.10
B-20	5.20	.39	1.00	9.14	.05	1.00	9.29	.05
B-24	6.52	.44	1.30	7.78	.11	1.00	7.63	.07
Mean	7.66	.361	1.32	8.00	.132	1.00	7.89	.111
SD	1.55	.071	.26	.66	.059	----	.80	.073

a day than the men on Ship A, but the total sleep quantity for most men was well within the normal range of variation (7.5 ± 1 hour; see White, 1975, and Webb and Cartwright, 1978).

Seven of the subjects averaged less than 6.5 hours of sleep a day, and three, A-17 (5.23 hr/day), B-5 (4.75 hr/day), and B-20 (5.20 hr/day), were conspicuously short sleepers. Subject A-17 was sick throughout the recorded period: notes in his log indicate he did not sleep well. Subject B-5 worked very long hours and work may have impinged on his sleeping time. His sleep quality and SSS values do not indicate above average fatigue, however, and he was a relatively short sleeper in the post-patrol period. Subject B-20 is of interest because he was a long sleeper ashore (9.14 hr/day) and reduced his daily sleep time by about 4 hours. He logged over 2 hours a day as recreation, and his sleep quality and SSS values suggest he simply felt little need for sleep.

3.2.2 Patterns of Sleep: The Number of Sleep Episodes. One of the clearest differences between shipboard and shore sleep is the replacement of the monophasic shore sleep by a multiphasic sleep in which the number of sleep episodes averages about 1.33 per 24-hour period. The men on Ship A working on the 6:18 schedule logged an average of 1.24 sleep episodes per 24-hour period. Those working on the 6:12 schedule logged significantly more sleep

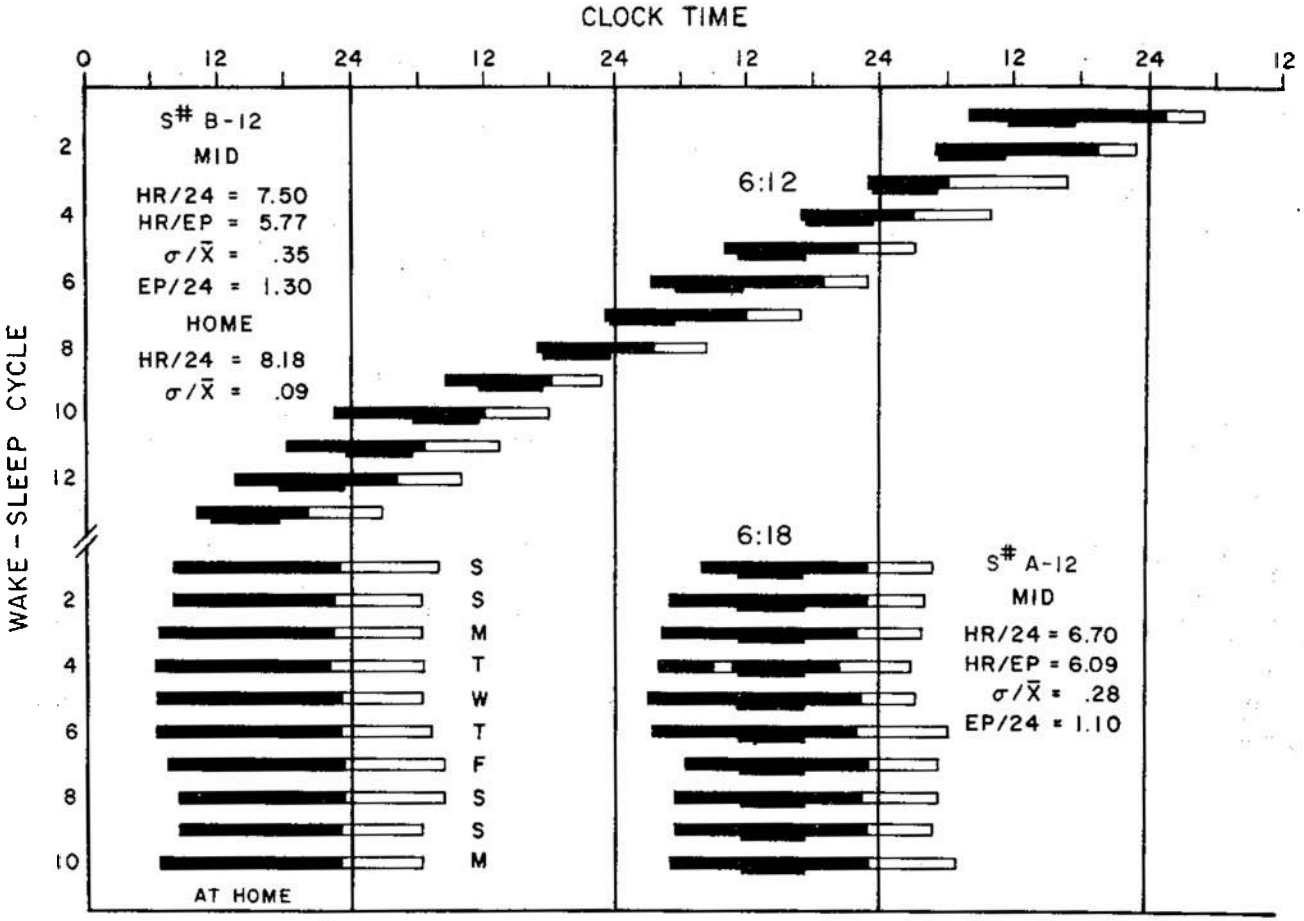

FIGURE 2. Graphic representation of the sleep-wake cycles of subjects B-12 and A-12. Time of day is given on the X-axis. Each horizontal bar represents one complete activity cycle. The black portions of the bars represent waking time and the white portions, sleep. Watches are indicated by the thicker sections of the bars. Ten days (13 sleep-wake cycles) from the log of a man standing a 6:12 watch are shown in the upper half of the figure. Ten days from the subject's post-patrol log are plotted in the lower left quadrant of the figure. Ten days from the log of a subject standing watch on the 6:18 schedule are plotted in the lower right quadrant.

episodes per day (1.41; $t(37) = 2.81$, $p = .008$). The difference appears to be related to the activity cycle fostered by the 6:12 watch rotation.

The activity cycles of two "typical" subjects standing 6:12 and 6:18 watches are depicted graphically in Figure 2. The abscissa is time of day. According to the convention of Aschoff (1978) and Wever (1979), each bar represents a complete activity cycle, with black indicating waking time and white representing sleep. Watches are represented by the thick portions of the bars. Successive cycles are stacked one below the other. Each bar begins at the time of day the proceeding one ended. Activity cycles systematically different from 24 hours appear as stair-steps in figures of this kind.

In the upper half of the figure, 10 days (235 hours) from the log of a subject (B-12) standing watch on the 6:12 schedule are plotted. Note that the precession of the watch period makes it impossible to obtain sleep at the same time each day. There are 13 watches and 13 complete activity cycles in 10 days, resulting in an activity cycle of approximately 18 hours.[3] The length of sleep episodes is also very variable. The 10-day post-patrol record of this subject is plotted in the lower left quadrant of the figure. Both waking and sleeping periods are much more regular (though he sleeps late on weekends). The activity of subject A-12, standing watch on the 6:18 schedule, is plotted in the lower-right quadrant. Even under this more normal routine, the sleep periods are more irregular than were observed in the post-patrol logs from the men of Ship B.

In the Ship B sample, the number of sleep episodes declined over the course of the patrol. Fifteen men on 6:12 watches returned logs covering the first and third periods (four men switched from 6:12 to 6:18 watches and four of the logs were incomplete). For these 15 men, the average daily sleep time remained unchanged, but the number of episodes per day declined from 1.50 to 1.34 ($t(14) = 2.28$, $p = .039$).

For the four men who changed from 6:12 to 6:18 watches, the average number of sleep episodes was reduced from 1.35 to 1.03 per day (one man took a nap in the final period), $\sigma/\bar{x}$ was reduced from .35 to .17, and the daily total sleep was reduced from 8.03 to 7.15 hours. The sleep quality statistics showed that the quality of sleep remained unchanged.

3.2.3 Patterns of Sleep: The Length of Sleep Episodes. The percentage of sleep episodes of various lengths is presented in Table 5 (overleaf). On Ship B, the distribution was symmetrical around a mean of 6 hours. On Ship A, the overall distribution was bimodal, with peaks at 6 and greater than 8.5 hours.

Fewer than 15% of the episodes were 2.5 hours or shorter, and a substantial fraction of these were separated from a longer sleep period by less than 1.5 hours, suggesting interruption and resumption of a planned longer sleep. With a few exceptions (A-13, A-19, A-22, B-9, and B-13), napping did not appear to be common in this population.

The bottom line in Table 5 presents the distribution of sleep episode

Table 5

Sleep Episode Durations

Ship	Episode Duration, Hours								
	>9	8	7	6	5	4	3	2	1
Ship A:6:18[1]	24.0	13.2	12.5	15.0	11.3	7.0	7.2	6.2	3.7
6:12[2]	14.2	6.3	13.2	19.8	18.2	10.6	9.9	5.3	2.6
Ship B:(All)	12.1	8.7	14.2	18.5	17.7	11.2	9.5	5.8	2.4
B Ashore	43.0	34.0	16.0	5.0	1.0	1.0	---	---	---
Kitty Hawk[3]	10.0	9.5	11.0	8.5	9.5	10.0	18.0	16.0	8.5

All entries are in % of recorded episodes.

1 Subjects A-8 through A-21, excluding A-19.

2 Subjects A-1 through A-7. The distributions for the 6:18 and 6:12 groups are significantly different ($\chi^2(8) = 32.85$, $p < .001$).

3 Sleep distribution from a sample of officers and enlisted men aboard the aircraft carrier USS Kitty Hawk. The numerical values are approximate, as they were read from Figure 4 of Johnson (1977).

durations recorded aboard the aircraft carrier USS Kitty Hawk while conducting operations off the coast of Viet Nam. The data are taken from Johnson (1977). Most of the men in this sample were nominally standing a traditional 4-on-8-off watch.

3.2.4 Regularity of Sleep. The regularity index ($\sigma/\bar{x}$) provides a useful adjunct to the sleep frequency data, although the size of the index is affected by both short naps and irregularity in duration of sleep. The sleep periods for subject B-12 depicted in Figure 2, though occurring regularly in relation to the watch cycle, varied considerably in duration. This irregularity is reflected in the $\sigma/\bar{x}$ value of 0.35. The previously mentioned reduction in the number of sleep episodes between the first and third patrol periods on Ship B was accompanied by only a small decrease in the average value of $\sigma/\bar{x}$ (from 0.42 to 0.36). There was a correlation of .51 between $\sigma/\bar{x}$ and number of sick calls recorded on Ship B. This is most parsimoniously interpreted as reflecting increased napping while sick.

3.2.5 Sleep Quality. Sleep quality was assessed by four questions on the activity logs. Individual responses to SQ-2 and SQ-3, averaged over 30 days, are given in Table 3. Between-subjects analyses of variance (ANOVAs) showed no significant difference between the on-patrol sleep quality, mood, and SSS values of the men who returned post-patrol logs and those who did not. Responses to SQ-1, SQ-2, and SQ-3 for the 11 men from Ship B who returned post-patrol logs are presented in Table 6 (overleaf) for each 10-day sub-sample.

Inspection of Table 3 reveals a wide variation among individuals, but the average response to the sleep quality questions indicated that difficulty in getting to sleep (SQ-1) was "slight" and that subjects felt "moderately" well rested when they awoke (SQ-2). However, subjects felt that they could have used more sleep upon awakening from 50% of sleep episodes (SQ-3). Inspection of Table 6 shows that responses to the sleep quality questions did not vary systematically across sampling periods. Subjective sleep quality on patrol was not as good as in the post-patrol period, but the difference was not large.

Subjective sleepiness upon retiring, as measured by the Stanford Sleepiness Scale (SSS), was positively correlated (.47) with the individual's average workload during the patrol. Patrol SSS values were negatively correlated (-.47) with the number of previous patrols, but not with age ($r = -.14$, ns). Stanford Sleepiness Scale values were not significantly different in patrol and post-patrol records.

3.3 Moods

Average patrol and post-patrol mood scale scores for the 11 men in the post-patrol sample are presented in Table 6. Average waking and retiring values of "activation" (TA), "activity" (MA), and "happiness" (MH) in the patrol and post-patrol periods were analyzed by means of separate within-subject ANOVAs. The Fs and associated significance levels are given in the table. Periods that differed significantly were determined by application of the Newman-Keuls procedure, summarized in the last two

Table 6

Sleep Quality, Mood, and Sleepiness, On and Off Patrol

	Sleep Quality			Waking Mood			Retiring Mood			
Sample	SQ-1	SQ-2	SQ-3	TA	MA	MH	TA	MA	MH	SSS
P 1 Mean	1.62	2.27	.52	2.20	2.28	2.25	1.84	2.03	2.30	3.66
SD	.52	.49	.27	.43	.40	.51	.55	.53	.60	.76
P 2 Mean	1.43	2.00	.41	2.08	2.22	2.26	1.80	1.95	2.21	3.64
SD	.51	.42	.21	.67	.60	.59	.66	.59	.58	.88
P 3 Mean	1.65	2.10	.40	2.28	2.35	2.34	1.79	1.92	2.19	3.78
SD	.64	.57	.31	.82	.75	.83	.63	.56	.69	.96
Post Mean	1.27	1.61	.34	2.96	3.13	3.40	2.47	2.62	3.18	3.42
SD	.39	.46	.28	.34	.31	.34	.59	.46	.39	1.00
F(3,30) =	5.54	12.34	2.01	11.08	16.41	24.33	7.08	9.07	17.84	.93
p =	.0038	<.0001	=.1337	<.0001	<.0001	<.0001	<.0010	<.0002	<.0001	=.4383
Post ≠	1,3	all	-----	all	all	all	all	all	all	-----
p	<.05	<.01	-----	<.01	<.01	<.01	<.01	<.01	<.01	-----

Tabled values are for the 11 men returning post-patrol logs.

TA: Thayer Activation Scale. MA: Mood Activity Scale. MH: Mood Happiness Scale.

P 1: Early patrol sample. P 2: Mid-patrol sample. P 3: Late patrol sample.

Post: Post-patrol sample. Post ≠: Patrol periods where values differed significantly from post-patrol values, as indicated by the Newman-Keuls procedure. The significance of the differences indicated are given in the bottom line. None of the patrol values differed significantly over the 3 patrol periods.

lines of the table. Inspection of the table shows that average mood scores were constant throughout the patrol, neither declining nor improving as the end of the patrol grew near.

Composite waking (WM) and retiring mood (RM) scores were created by calculating the average of TA, MA, and MH values. This combination emphasizes feelings of "activation", which were stronger upon waking than retiring. Feelings of "happiness" were not affected by the time the scales were filled out. The correlation between WM and RM was .82. There were modest (and expected) correlations between WM and two of the sleep quality measures while on patrol, -.44 with SQ-2 ("How rested do you feel?") and -.39 with SQ-3 ("Could you have used more sleep?"). Waking mood was also correlated modestly (.39) with number of previous submarine patrols. The correlation of average RM with SQ-3 was -.40 and with SSS was -.45.

Mood scale responses indicated significantly greater "activation" (TA, MA) and "happiness" (MH) in the post-patrol period.

4. DISCUSSION

4.1 Work

The six-hour watch length used on U.S. Navy nuclear submarines requires 8 hours of watch standing a day (four 6-hour watches in three days) from men in three-section watches and 6 hours a day from men in four-section watches.

Additionally, non-watch work averages 2.9 hours a day, with large variation from one man to the next. Some of this variation may reflect the policies of individual supervisors. In some work groups, all necessary work was done by watch-standers, but in others watch-standers only monitored and operated equipment, while repair and maintenance were done by off-watch personnel. For most individuals, non-watch work was likely to vary considerably from day to day. The men on Ship A logged 0.8 hours more additional duty a day than those on Ship B. This may be due to the fact that Ship A was preparing for an Operational Readiness and Safeguard Evaluation, which is the most demanding inspection in the submarine force.

The men on Ship B recorded more hours of study than those on Ship A. This difference may be due to the inclusion of more junior (in rank) men in the Ship B sample. Several of them were working to earn their submarine qualification, which generally requires a year of intensive study. Although the correlation between pay grade (rank) and logged study time was -.37, it is evident from inspection of Table 2 that study accounts for a significant amount of time for men of all ranks.

For the men standing 6:12 watches the total workload was about 12.4 hours a day. This figure is comparable to the 12.2-hour workload reported by the enlisted surface ship and aircrewmen surveyed by Williams, Malone and Bokesch (1975), although study was not a separate response category in their questionnaire. Although the observed workload was substantial, it is not excessive in the sense of being likely to lead to physiological or performance deficit.

4.2 Sleep

The submarine crewmen in this study averaged 8 hours of sleep a day. This average is longer than the 7 hours a day reported by Colquhoun, *et al* (1978) or the 5.75 to 6.5 hours reported in the Schaefer, *et al* (1979) study, which was conducted aboard the same class of submarine. Kleitman (1949) reported a daily average of about 9 hours for the crew of a diesel submarine. These differences in reported averages, combined with the differences between ships in the present study, suggest that the amount of sleep obtained by crewmen varies from ship to ship, perhaps as a function of the ship's mission. The average daily sleep for the crewmen in our samples is much longer than the minimum required to maintain effective performance (see Johnson and Naitoh, 1974; Naitoh, 1976; Webb and Agnew, 1974). The ample size of the daily average suggests that chronic partial sleep deprivation is unlikely to be a significant problem among submarine crewmen.

Sleep fragmentation is defined as the breaking up of the daily sleep quota into a number of short episodes (Johnson and Naitoh, 1974). Sleeping once every watch cycle of 18 hours was by far the most common sleep pattern observed for men on 6:12 watches. Since this results in 1.33 sleep episodes per 24-hour day, the sleep of submariners working on this schedule may be said to be somewhat fragmented, but the degree of fragmentation is not as severe as that observed in Naval aviators and surface ship crews by Naitoh (in press). Fragmented or multiphasic sleep is known to be less effective for recuperation from daily fatigue (Taub, 1979). Thus, the finding that the question (SQ-3) "do you feel that you could have used more sleep?" was answered "yes" 50% of the time is consistent with the existence of mild sleep fragmentation.

In normal sleep ashore, the length of sleep episodes clusters around 7.5 to 8 hours (Webb and Cartwright, 1978; Naitoh, in press). On Ship B, the distribution was fairly symmetrical around 6 hours and on Ship A, it was bimodal, with peaks at 6 and > 9 hours. The difference between the two ships was seen to be a reflection of the proportion of men standing 6:12 watches. There are many things to do when off-watch and it is difficult to achieve sleep durations longer than 8 hours with regularity on a 6:12 watch rotation. Because the sleep periods were so variable, it is likely that some of the episodes longer than 8.5 hours in both samples may have been a response to short-term sleep deficits. That is, a long sleep may have been taken to make up a perceived sleep debt. This pattern is seen in the second and third cycles of subject B-12 in Figure 2. Such "catch-up" sleeps are almost impossible on the traditional 4:8 watch schedule (Stolgitis, 1969).

The distribution of sleep episode lengths from a surface ship, the USS Kitty Hawk, was included in Table 5 for comparison with the distribution of submariners. Most of the men in the Kitty Hawk sample were nominally standing watch on the traditional 4:8 schedule. The contrast with the submarine distribution is striking. Although

the total daily sleep time was not reported, it is evident that the sleep of the men on the carrier was considerably more fragmented than that of the submarine crewmen in the present study.

The Stanford Sleepiness Scale values averaged 3.74 while on patrol. This value is close to the baseline SSS of 3.6 for five male college students reported by Hoddes, *et al* (1973). Glenville and Broughton (1979) reported a lower baseline average (2.8) for eight male subjects, 20 to 46 years of age, and Naitoh (in press) found an even lower baseline value, 2.3, for 22 U.S. Navy recruits. Loss of a single night's sleep increased SSS values by two units in the Hoddes, *et al*, and Glenville and Broughton studies, and by one unit in the Naitoh study. It seems reasonable that a significant chronic sleep debt would have been reflected in elevated SSS scores, but this was not observed. The SSS values for submarine crewmen on patrol did not differ significantly from the baseline provided by the post-patrol logs, which suggests that the quantity of sleep was entirely adequate.

Surprisingly, inspection of Table 6 reveals no evident relationship between the daily average sleep on patrol and at home. Subjects B-9 and B-17 increased their daily sleep while on patrol, while subjects B-5 and B-20 decreased their daily sleep during the patrol rather dramatically, from 7.05 hours to 4.75 and from 9.14 to 5.20 hours of sleep per day. The effect of such reduction in total sleep time upon performance is uncertain. Webb and Agnew (1974) and Friedmann and her colleagues (1977) have shown that some individuals may significantly reduce daily sleep time with no apparent effects on performance, though individual tolerance may vary widely.

Responses to the SQ-2 question, "how rested do you feel?", averaged 2.11 ("moderately") during the patrol for all subjects and 1.61 in the 11 post-patrol records. Responses from the aircrewmen on extended missions studied by Harris, Pegram, and Hartman (1971) averaged 2.53 follwoing sleep periods while working on a 4-on-4-off schedule, and 2.41 when working on a 16-on-16-off schedule. In the post-mission recovery period, the average response was 1.65.

The question, "do you feel you could have used more sleep?" (SQ-3), was answered "yes" 50% of the time by the submariners on Ship B. The aircrewmen in the Harris, *et al* study working on the 4:4 schedule responded "yes" to this question 90% of the time and those on the 16:16 schedule 80% of the time. In addition, the submarine crewmen experienced little difficulty in falling asleep (the mean SQ-1 response was 1.59), whereas 50% of the aircrewmen experienced some difficulty in falling asleep when working on 4:4 or 16:16 schedules.

Taken together, the sleep quality measures indicate that the sleep of submariners working on an 18-hour activity cycle, while slightly inferior to off-patrol sleep in its subjective quality, is more effective in combating fatigue than the sleep obtained by aircrews on extended missions, although this may be more

a reflection of the submariners' more stable environment than of sleep schedule or workload.

4.3 Mood

The most striking feature of the mood data presented in Table 6 is that the patrol values cluster around 2.0, which corresponds to the neutral or "?" point on the scale. A significant proportion of respondents gave average responses on the negative side of neutral, suggesting unhappiness and lack of energy. Inspection of Table 6 shows that moods were constant throughout the patrol, neither declining nor improving as the end of the patrol grew near. Both "activation" and "happiness" scores were higher during the post-patrol period.

The diminution of mood while on a submarine patrol has been observed previously (Kleitman, 1949; Messina, 1968). Taub and Berger (1974, 1976) have shown that simply shifting the usual sleeping times as little as 3 hours (while holding total hours slept constant) will lower mood scale scores. It is thus possible that the depression of mood scale values in the present study may be related to the 6:12 watch schedule. However, the depression of mood could, with equal plausibility, be attributed simply to living conditions aboard the ship, such as crowding, confinement, or long hours of work (it should be noted that these conditions are hardly unique to submarines). It is perhaps significant that comments indicating "homesickness" were made in the space provided for notes in several of the logs.

5. CONCLUSION

5.1 Work

The workload of submariners on deployment is substantial, although individual differences in workload are pronounced. For all ranks, study constitutes a significant proportion of the workload. In general, men average about 4.5 hours of non-watch work and study daily, in addition to standing watch for 6 or 8 hours.

5.2 Sleep

For men standing 6:12 watches, the progressive moving up of on-watch times makes it impossible to take their daily sleep at the same time each day. The usual mode of accomodation to this watch schedule is to take a single relatively long sleep at some time during each 12-hour off-watch period, thus establishing a rough 18-hour periodicity in the sleep/wakefulness cycle.

Sleep on submarines may be considered mildly fragmented in the sense that daily sleep quota is not taken in a single episode at a usual time of day. Even for men standing 6:18 watches, ship-board sleep is considerably more irregular than in most shore settings.

Regardless of the watch schedule, the long-term average quantity of sleep in 24 hours is well within the normal range of variation. The average duration of sleep episodes is very variable, but that average appears to be long compared with other kinds of war-ships. It is considered that chronic

sleep deprivation is not likely to be a significant stressor on submarines.

The quality of sleep is somewhat lower on patrol than at home, but the sleep quality indices do not suggest that sleep quality is so poor as to be considered a problem. The slight reduction in sleep quality may be related to the 18-hour cycle, or simply to shipboard living conditions.

5.3 Mood

"Activity" and "happiness" mood scale values were significantly lower on patrol than in the post-patrol period. On-patrol means clustered around the neutral value. To the extent that mood affects performance or the decision to remain in the service, this finding merits further investigation.

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FOOTNOTES

The interpretations and opinions contained in this article are those of the authors only and do not necessarily represent the view of the U.S. Navy.

1 The analysis reported is confined to the activities of enlisted men because only three officers returned logs, and two of them were the captains of the two submarines. The 11th man in the post-patrol sample is a lieutenant who returned a post-patrol log. The number of these returned was too small to allow the luxury of excluding him from the patrol:post-patrol sleep and mood comparisons.

2 We have followed the recommendation of Dunn (1961) to report exact probabilities where possible.

3 The activity logs of those men participating in the Naitoh, Beare, Biersner, & Englund study of circadian rhythms were analyzed for periodicity by the Naval Health Research Center's "Period" program (see Naitoh, Sunderman, Townsend, & O'Reilly, 1976). The average length of the sleep-wake cycle was found to be 18.8 hours.

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Hours of work and sleep were recorded in daily activity logs by 46 enlisted men on two Fleet Ballistic Missile submarines during routine patrols. Total working time (watch standing, non-watch work, and study) averaged 12.0 hours a day. Daily sleep time averaged 8 hours a day on one ship and 7.5 on the other. Sleep was mildly fragmented in that the men averaged 1.3 sleep episodes, of somewhat less than 6 hours duration, in 24 hours. Thirty of the men were standing watch on a 6-hours-on-12-hours-off rotation which effectively imposed

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an 18-hour cycle on their activities. Questions in the logs were used to assess subjective sleep quality and sleepiness. Sleep quality on patrol was not as good as in a post-patrol period, but the difference between on- and off-patrol sleep quality was small. The 6-on-12-off watch schedule appeared to result in less sleep fragmentation than the traditional 4-on-8-off schedule.